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# Multinut Opener Cum Tightner for Four Wheeler

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## I. ABSTRACT

As the standard of living in India has increased, most of the families have at least one vehicle, typically, car, to move easily and quickly. With the increment of the number of cars in the road, the number of cars' problem due to tire failure has increased. Often, the car is provided with tire wheel nuts remover and jack for instance spare tire replacement. Nevertheless, due to the difficulty in applying the required torque to remove the nuts, most of the time, driver rely on the tow truck and available nearest mechanic to solve the problem. This always happen to the elderly or female drivers. Based on the capability of torque application by these drivers, a vehicle all-wheel-nuts remover is designed. The remover is designed to be ergonomic to be used, easy maintenance, easy storage, easy to handle and able to remove all nuts at once

Adjustable Multinut wheel opener is a special purpose tool made to open/close all the nuts of a wheel in one time with less effort. Although various methods are used for opening nuts, they require a lot of effort to open a single nut. The main objective of work is to develop a single tool with multiple mechanisms, which can be made use during assembling and dismantling of wheels in automobiles. It can be successfully used as a standard tool irrespective of the model of the vehicle. Also it can be used in assembly line of automobiles, garages, workshops and service stations.

The main concept of the proposed system is nut fitting & removing without human help for driving. The heart of the project and implementation is motor. The components used here for efficient function of individual blocks are Motor, Nut fitting arrangement (spanner) and spur gear arrangement. The main objective of the model is to remove the nuts of a wheel at once and not one at a time. The principle of the model is the usage of bevel gear to transmit relative motion to other gears. Generally bevel gears are used for transmitting power between non parallel intersecting shafts. So bevel gear arrangement is used for actuating the four socket spanners at a time. Twelve driven gears and one pinion gear are used. The cam and follower mechanism is used for making the project adjustable. For this purpose radial cam is used because the follower moves in the direction perpendicular to the cam axis. And spherical face follower is used because the side thrust and wear is considerably low. The pinion gear is meshing with four auxiliary gears which are in turn connected to a gear whose axle containing the socket spanners at its end. The auxiliary gear connected to a hollow shaft (main shaft) which is acting as a guide for follower. The other end of the follower is connected to a bevel gear. A lock nut arrangement is provided for connecting the main shaft to follower at any desired position. When the pinion is rotated the auxiliary gears are also rotated which in turn gives a rotary motion to the socket spanner. This helps to tighten or loosen the bolts. The adjustment for removing the bolts which are having different pitch circle diameter is achieved by rotating the cam. The followers are in contact with cam when the cam is rotated the follower will move linearly. After reaching a desired position the follower is locked with the hollow shaft to make them to rotate as a single shaft. Then the cam is brought back into its initial position to prevent the cam from severe wear while the follower is rotating. The pro-e model of our project is shown in Fig no. 1

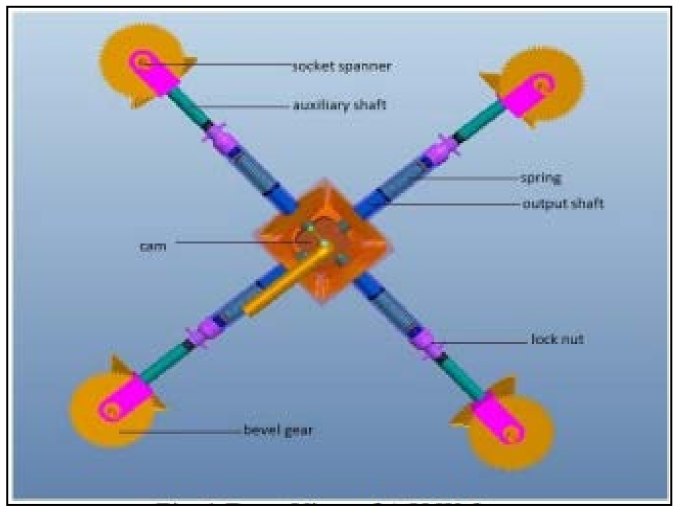



**Figure no. 1**
**CAD Model Of The Proposed System**

## II. INTRODUCTION

Engineering in general, and Mechanical engineering in particular, deals with a wide spectrum of products, ranging from large and complex systems comprising of numerous elements down to a single component. Apart from being a physical object, a product can also be a service that requires the application of engineering knowledge, skills and devices to be useful to society. A service falls under the category of a system in that it is carried out with the help of personnel, facilities and procedures. The service offered by an automobile maintenance and repair garage would be a typical example from mechanical engineering. Even computer software could be treated as an engineering product. It is also created using engineering knowledge and skills. In the following, the term product when used alone denotes the object to be designed and made with the help of engineering knowledge and skills, irrespective of whether it is a large system, a simple machine, a component or a service. A general understanding of the nature of product is a prerequisite for designing it. A complex product can be subdivided into sub-assemblies or sub system, component etc. Frequently the planning, layout and design of a complex multi element product is an interdisciplinary effort, requiring the expertise and skills not only of several engineering specialization but even non engineering ones. It is always preferable that our work should be easy and fast. But easy and fast working requires some technical skills to work efficiency and properly. In a day-to-day life there are many problems where there is a need of lot of effort and time to do that specific work. A little but important work that all people would do often is opening a wheel of a vehicle. It is a fact that a huge effort is required to open a single nut of a car wheel and it will become a tedious task to open the wheel in extreme atmospheric conditions. It also creates problem when there is an emergency situation. For a car, the tool set-up for each vehicle is a T-nut wrench and car jack which is hard to use for a women or teen to open their car's nut. One of the problems of a vehicle is tire problem. If the vehicle tires have some problem then the user must remove the tires and fix the problem. And for a car user, it's difficult to remove tire's nut especially for women users. The obstacles are time waste and force needed. In Malaysia automotive market there is no tool that is easy to use to remove the nuts. The time to open a car's tire nut is too long and has waste the car user's time with utilization of high force that is hard for women users. To resist the time waste and high force needed a tool have been designed to remove four tire nuts in one time with force used decrement. Here is the solution to the problem mentioned above by Adjustable Unified Wheel Opener, it is a special tool designed for opening a wheel with ease. It is so designed that it can open all the four nuts of a car wheel in one time. And the most desired achievement is that, the total effort and time needed in the process is very less. It can open and also refit the wheel with the same tool easily. Tool is simple in design, easy to use and easily portable along with the vehicle.

The tool used to remove the wheel nuts should be designed for ergonomic, easy to handle and requires small space for storage. The tool is also function as wheel nuts tightener. Nonetheless, it is difficult for women and the elderly drivers due to high required torque to remove the wheel nuts. In addition, if the nuts are successfully removed, the problem to retighten the nuts will follow. If the required torque is not applied in tightening the nuts, the nuts will lose, and this will jeopardize the driver's safety. Impact wrench used to remove wheel nuts is also consuming time in automotive maintenance industry. For these reasons, to avoid time wasting and a lot of energy used to change the tyre, a special tool is designed and fabricated to allow driver or mechanic to remove four wheel nuts at once with little energy consumption

## III. FEATURES

- multiple mechanisms,
- assembling,
- adjustable,
- dismantling,

**Literature Review**

*Forces Involved:*

Breaking loose all four over tightened lug nuts required totally discharging two full batteries in the cordless impact wrench—obviously, the last person to install that wheel had over tightened the nuts with a powerful pneumatic impact wrench. The installed lug nuts on the spare with a torque wrench, carefully adjusted to the correct 100 ft-lb, which we looked up in the owner's manual. That process got us the stink eye from the car's otherwise grateful owner—who was convinced that the proper way to tighten the lugs required that pneumatic wrench again, or at least jumping up and down on the end of the lug wrench.

Car manufacturers specify a proper tightening level, a torque value expressed in foot-pounds, for every fastener on your car. Torque is a rotational force applied around a point or, in this case, a nut. Put a 1-foot-long wrench on a nut and apply 10 pounds of force to the opposite end. You're now twisting that nut with 10 ft-lb (distance times force, or 1 foot times 10 pounds). Use a 2-foot-long wrench and apply 50 pounds of force, and you'll have 100 ft-lb, which, happily, is just about as long as most lug wrenches, and as much force as most elbows are happy cranking on.

While most mechanics rely on a well-calibrated elbow to tighten things, it's vitally important that the tightness of a fastener fall within a fairly narrow range. Too loose and there's the danger of the nut or bolt spontaneously unscrewing down the road. Or maybe the gasket or O-ring fitting clamped by that bolt will leak. Too tight and there are other risks: The bolted-together part may be compressed, bent or otherwise damaged. The bolt shank could break, or the threads may strip, providing no clamping force at all. The best way to tighten fasteners is with a device called a torque wrench.

Let's discuss what happens when you turn a nut or bolt head. The threads are a form of inclined plane or wedge, the simplest type of tool. As the inclined plane is wedged (turned) into the threads, it applies a force along the bolt's length, effectively making the bolt a tension spring. This tension in the bolt shank clamps two parts together. If the clamping force is greater than the load exerted between, say, the head and the block, those two pieces will never spontaneously get loose. And the more twisting force you apply to the bolt head or nut, the more clamping force in the joint. So just tighten it until it won't come loose, right?

Wrong. Differences in overall bolt length, the material of the clamped parts, the presence of a gasket between the two parts, and even the alloy of the bolt itself affect the proper torque. Also, the proper torque value takes into account the friction between the threads, which is the single biggest variable that affects the relationship between the torque applied to the bolt head and the clamping force. Friction arises from the threads as well as the rotating bolt face scrubbing along the stationary workpiece. Overcoming friction can account for as little as a few percent or as much as 50 percent of the force needed while tightening a nut or bolt. And that means that the clamping force can vary widely—not well when you're installing a cylinder head or an intake manifold.

*Gears:*

A bevel gear is one of the most fundamental types of gear, it is widely used in power transmission systems of aircrafts, automobiles and engineering machines, etc..Bevel gears are cut on conical blanks to be used to transmit motion between intersecting shafts. Straight bevel gears are the most economical of the various bevel gears, owing to their ease of manufacture. The figure 2 below shows a bevel gear arrangement.

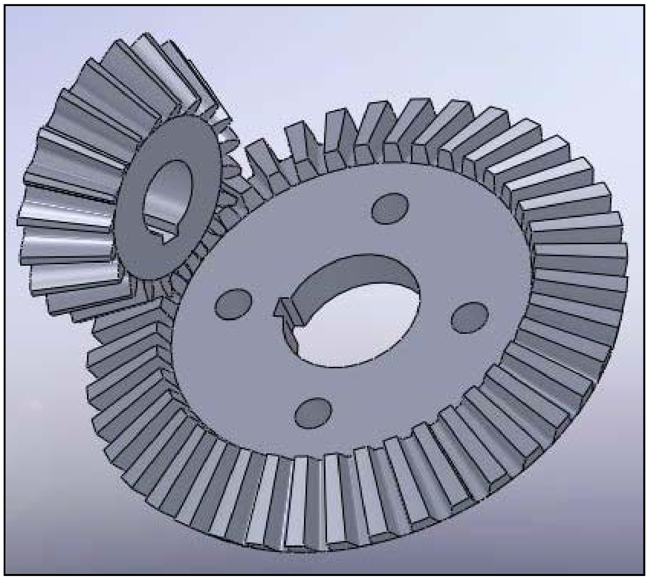


**Figure no. 2**
**Straight Bevel Gear**

[1] *Motor:*

[2] Torque is the twisting force supplied by a drive to the load. In most applications, a substantial amount of torque must be applied to the driven shaft before it will even start to turn. In the English System, the standard units of torque as used in the power transmission industry are pound inches (lb. in.), or pound feet (lb. ft.) and, in some cases, for very low levels of torque, you will encounter ounce inches (oz. in.).

*Torque Basics:*

At some time, we have all had difficulty in removing the lid from a jar. The reason we have this trouble is simply that we are unable to supply adequate torque to the lid to break it loose. The solution to our dilemma may be to: 1) grit our teeth and try harder, 2) use a rubber pad, or cloth, to increase the ability to transmit torque without slippage, or 3) use a mechanical device to help multiply our torque producing capability. Failing on all of the above, we may pass the jar to someone stronger who can produce more torque.

If we were to wrap a cord around the lid and supply a force to the end of the cord through a scale, as shown in Figure 3, we could get the exact measurement of the torque it takes to loosen the lid.

The torque required would be the force as indicated on the scale, multiplied by the radius of the lid.

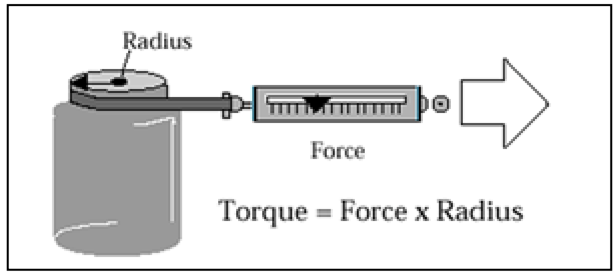



**Figure no. 3**

**Example of torque**

The motor that we are going to use is a torque motor i.e. it works for providing torque only and it provides less speed. So it works to provide only torque hence, the name torque motor

*Fabrication:*

In the fabrication of tool, two processes are performed; milling and fitting. Since the gears are not available in the market, custom designed gears need precision milling and fitting processes. Once the tool is ready, an experiment is performed with the intention to find the time required to remove the nuts. This result is then compared with the time required using ordinary L-shaped wrench. Experiment using impact wrench is also performed.

*Material Selection:*

400 & 450HB Abrasion Resistant Steel

• 400 and 450HB is through hardened, quenched and tempered abrasion resistant steel and is the most widely used of the wear resistant grades for all weld on wear components

• Used in high impact and abrasion applications such as bucket, blade and truck deck liners, weld-in cutting edges, wear strips, ripper shanks and crusher plates

• This plate is 3-4 times the abrasion resistance and strength of mild steel with an excellent combination of workability, weld ability and formability

• Thickness range available is from 6mm to 90mm. Sheet size: 6000mm x 2500mm

500HB Abrasion Resistant Steel

• 500HB is through hardened, quenched and tempered abrasion resistant steel, providing the ultimate wear resistance for severe abrasion

• Applications for this steel include bolt-on cutting edges, crusher plates, wear strips and any other sliding wear surfaces

• This steel will last up to 10 times the wear life of mild steel and will outperform the 400-450HB steel due to its mechanical properties

• Thickness range available is from 10mm to 50mm. Sheet size: 6000mm x 2500mm

**Problem Definition**

*Pitch Circle Diameter (PCD):*

The pitch circle diameter is the diameter of the circle which passes through the centre of all the studs, wheel bolts or wheel rim holes. The bolt circle is determined by the positions of the bolts. The centre of every bolt lies on the circumference f the bolt circle. The important measurement is the bolt circle diameter also called Pitch circle diameter. PCD is shown in figure no. 4.

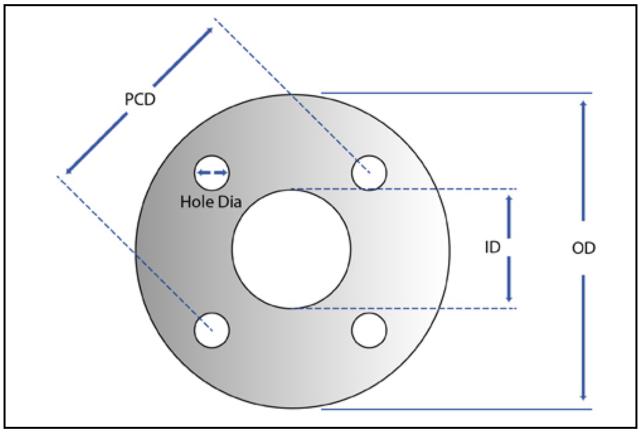



**Figure no. 4**
**Pitch Circle Diameter**

In India the standard sizes of PCD are as follows

- Maruti Swift 100
- Maruti WagonR 100
- Maruti Esteem 114.3
- Maruti Zen 114.3
- Maruti Omni 114.3
- Maruti 800 114.3
- Maruti Baleno 100
- Honda City 100
- Honda Accent 100
- Toyota Corolla 100
- Toyota Innova 114.3

*Lug nuts:*

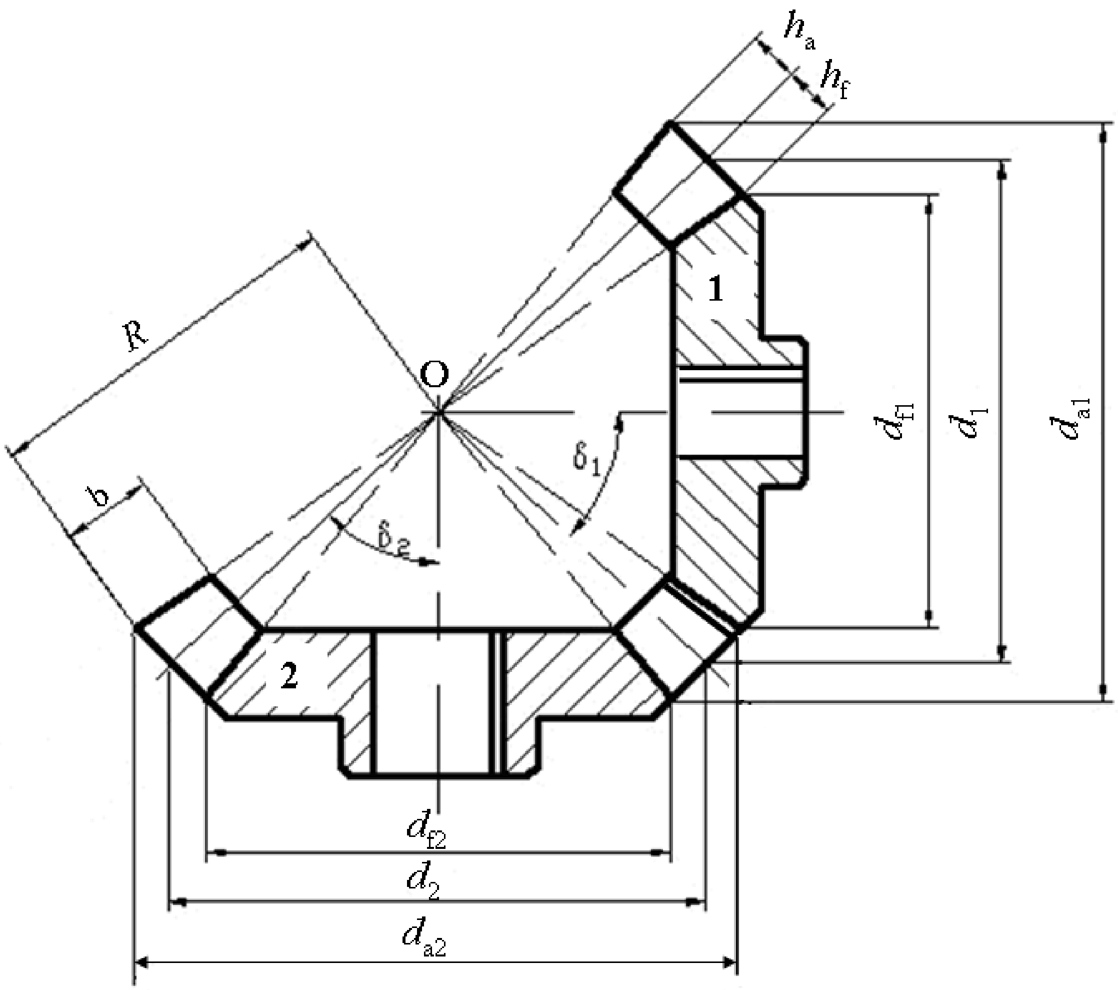
A lug nut is the nut with one rounded or conical (tapered) end, used on steel and most aluminum wheels. A set of lug nuts are typically used to secure a wheel to threaded wheel stud and thereby to a vehicle. The below figure no. 5 shows types of lug nuts.


**Figure no. 5**
**Types of lug nuts**


**Figure no. 6**
**Removing nut using T-wrench**


Hence in order to perform all the above things a design should be proposed which should be more convenient, cheaper and easy access. In the previous versions of unified wheel opener spur gear arrangement have been used for the uniform rotation of all the box spanners, in A.U.W.O system, bevel gear arrangement have been used, coupled with the shaft arrangement to transmit the power applied uniformly to all the four box spanners. And in further spring and lock - nut arrangement have been used to make the system adjustable to the required pitch length.

## Methdology




*Design of bevel gear*

*A. Basic principles and Theory*

The basic fundamentals of law of gearing have to be followed in designing the bevel gears. The Fundamental law of gearing states that, "For a pair of gear to transmit constant angular velocity ratio, the tooth profiles of these mating gears must be designed in such a way that the common normal (line n-n) or the line of action passes through a fixed point, or also known as the pitch point, on the line of centres."

*B. Design Parameters*

PCD (Pitch Circle Diameter) = 100 mm to 114.3 mm.
Common nut sizes = M16, M17, M18.
Torque required, T = 320 Nm (4 nuts).
Average force by human, F = 500N.
Length of handle, $L_h$ = 600 mm.
Gear material = Mild steel.
Module, m = 2 mm.
Pressure angle, = 20˚

*C. Design procedure for bevel gears and pinion*

Bevel gear
Power to be transmitted, P = 1.5 kW.
Torque, T = 320 Nm.
Speed ratio i = 1.
Z1 (gear) = 25 teeth, Z2 (Pinion) = 25 teeth.
Young's Modulus, E = $2\times10^3$ N/mm$^2$.

Cone distance,
$$R=\psi(i^2+1)\left(\left[\frac{0.72}{(\psi-0.5)\sigma}\right]2E*\frac{t}{i}\right)$$
= 30.206 mm.
Module, m = R/ {0.5 (Z12+Z22)1/2}
= 1.83 mm
≈ 2 mm.

*D. The dimensions for pinion & gear are as:*

Addendum, $h_a = 0.943\times m$
= 1.886 mm.
Dedendum, $h_f = 1.257\times m$
= 2.514 mm.
Outside diameter of pinion, $d_p = (T_p+2)\times m$
= 44 mm.

Outside diameter of gear, dg = $(T_g+2) \times m$
= 44 mm.

*E. Spring parameters*

Open coiled, ground ends.
Circular cross section.

*F. Design procedure for output shaft*

Shaft dimensions
Shaft-1 (Output shaft)
Outer diameter, $d_o = 1.5\ d_i$ (inner diameter).
Torque, T =300 Nm
Maximum shear stress, $t_{max}$ = 115 $N/mm_2$
= $(16Td_o)/(\pi(d_o^4-d_i^4))$
on substitution,
Inner diameter, $d_i$ = 16.23 mm
≈ 16 mm.
Therefore, Outer diameter, $d_o = 1.5\ d_i$
= 25 mm.
Length of shaft required, $L_o$ = 15 mm

*G. Design procedure for auxiliary shaft*

Shaft-2 (Auxiliary shaft)
Length of the shaft required, $L_a$ = 46.75 mm.
Outer diameter, $D_o$ = 15.5 mm.
Inner diameter, $D_i = 0.75\ D_o$
= 11.625 mm.

*H. Time consumption*

Time taken to remove a nut, t = 15 seconds
Setup time, s = 10 seconds
Total time, $T_t$ =4t
= 60 seconds (conventional)
Total time, T = t+s
= 10+15
= 25 seconds (our project)

*I. Design of Cam*

Maximum displacement required, x = 10mm.
Maximum space available for cam, d = 30mm.
Width of the cam, w = 21mm
Length of the diagonal, l = 30 mm

*Selection of motor*

An electric motor is an electrical machine which converts electrical energy into mechanical energy. The basic terms in motor are as follows

**Torque** (also called a moment) is the term we use when we talk about forces that act in a rotational manner. You apply a torque or moment when you turn a dial, flip a lightshwitch, drill a hole or tighten a screw or bolt.

As shown in the picture of a ratchet, a torque is created by a vertical force applied at the end of the handle. The force, F, applied to the ratchet as shown causes a tendency to rotate about point O. The force can be broken down into two components: a radial component, $F_{rad}$, parallel to the ratchet handle that does not contribute to the torque, and a tangential component, $F_{tan}$, perpendicular to the handle that does contribute to the torque. The distance from point O to the point of action of F is described by the direction vector, r. The moment arm, l is the perpendicular distance between point O and the line of action of F.

If we were to shorten the moment arm by applying the force closer to the head of the ratchet,the magnitude of the torque would decrease, even if the force remained the same. Thus, if we change the effective length of the handle, we change the torque (see equation 1).

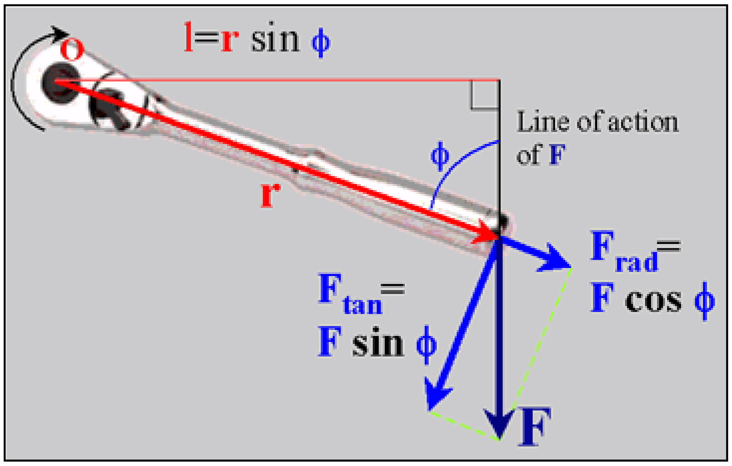



**Figure no. 7**

$$1)\ \text{Torque: } \tau = F \cdot r \cdot \sin(\phi)$$
$$\text{or: } \tau = F_{tan} \cdot r$$

**Speed (Angular Velocity)**

Motors are devices that convert electrical energy into mechanical energy. The D.C. motors that we have been dealing with here convert electrical energy into rotational energy. That rotational energy is then used to lift things, propel things, turn things, etc... When we supply the specified voltage to a motor, it rotates the output shaft at some speed. This rotational speed or angular velocity, $\omega$ is typically measured in **radians/second {rad/s}, revolutions/second {rps}, or revolutions/minute {rpm}.**

When performing calculations, be sure to use consistent units. In the English system, calculations should be done in degrees/second, and radians/sec for SI calculations. From the angular velocity, $\omega$, we can find the tangential velocity of a point anywhere on the rotating body through the equation tangential velocity, $v = r^* \omega$, where r is the distance from the axis of rotation. This relation can be used to compute the **steady state** (constant speed - no acceleration) speed of a vehicle if the radius and angular velocity of a wheel is known, or the linear speed of a rope as it is wound up by a winch.

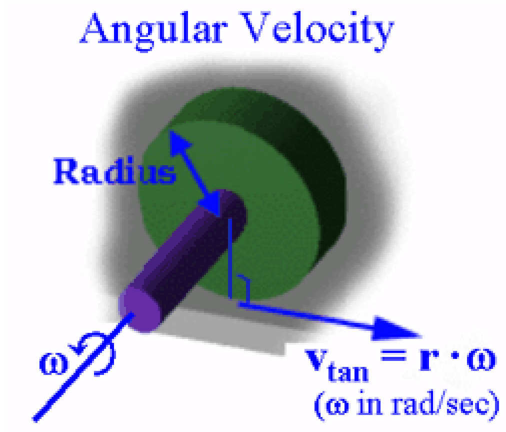



**Figure No. 8**
**Relation of speed and velocity**

*Power in Rotational Motion*

When you pedal a bicycle, you apply forces to a rotating body and do work on it. Similar things happen in real-life situations, such as a rotating motor shaft driving a power tool or a car engine propelling the vehicle. We can express this work in terms of torque and an angular displacement... What about the power associated with work done by a torque acting on a rotating body?

dW/dt is the rate of doing work, or power P. When a torque T (with respect to the axis of rotation) acts on a body that rotates with angular velocity W, its power (rate of doing work) is the product of the torque and angular velocity. This is the analog of the relation P = **F·v** for particle motion.

*Motor Characteristics*

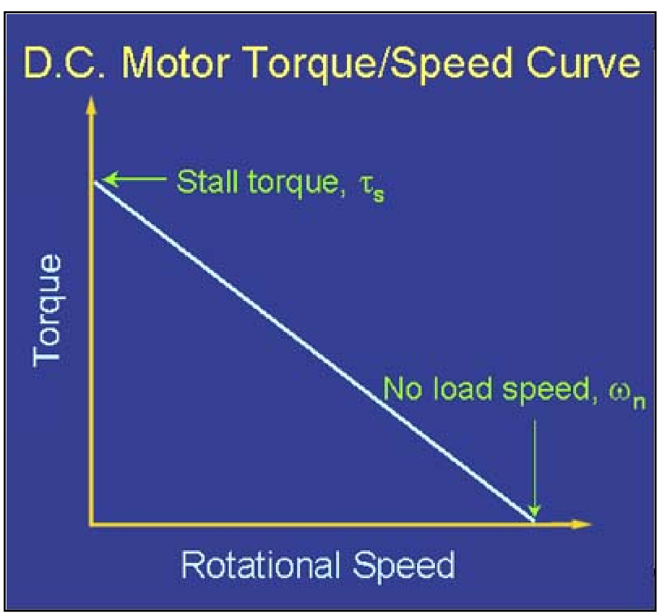



**Figure No. 9**
**Relation between torque and speed**

In order to effectively design with D.C. motors, it is necessary to understand their characteristic curves. For every motor, there is a specific Torque/Speed curve and Power curve.

The graph above shows a torque/speed curve of a typical D.C. motor. Note that torque is inversely proportioal to the speed of the output shaft. In other words, there is a *tradeoff* between how much torque a motor delivers, and how fast the output shaft spins. Motor characteristics are frequently given as two points on this graph:

- The stall torque, $\tau_s$, represents the point on the graph at which the torque is a maximum, but the shaft is not rotating.
- The no load speed, $\omega_n$, is the maximum output speed of the motor (when no torque is applied to the output shaft).

The curve is then approximated by connecting these two points with a line, whose equation can be written in terms of torque or angular velocity as equations 3) and 4):

$$3)\ \tau_{motor} = \tau_s - \omega\tau_s/\omega_n$$

$$4)\ \omega_{motor} = (\tau_s - \tau)\omega_n/\tau_s$$

The linear model of a D.C. motor torque/speed curve is a very good approximation. The torque/speed curves shown below are actual curves for the green maxon motor (pictured at right) used by students in 2.007. One is a plot of empirical data, and the other was plotted mechanically using a device developed at MIT. Note that the characteristic torque/speed curve for this motor is quite linear. This is generally true as long as the curve represents the direct output of the motor, or a simple gear reduced output. If the specifications are given as two points, it is safe to assume a linear curve.

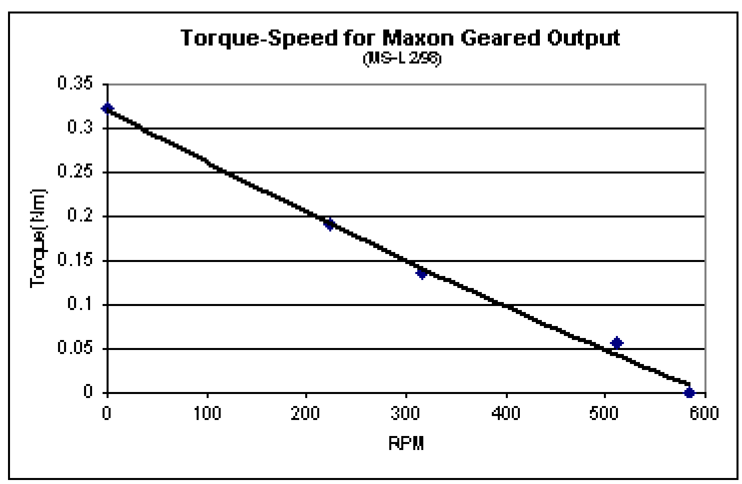
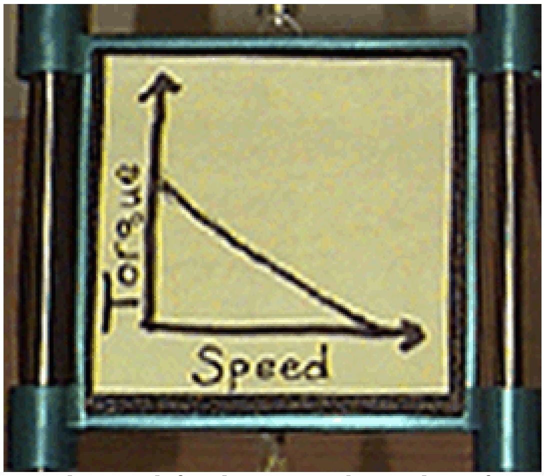



**Figure no. 9**
**Torque speed characteristics for Maxon geared output**




Recall that earlier we defined power as the product of torque and angular velocity. This corresponds to the area of a rectangle under the torque/speed curve with one cornerat the origin and another corner at a point on the curve (see figures below). Due to the linear inverse relationship between torque and speed, the maximum power occurs at the point where $\omega = \frac{1}{2}\ \omega_n$, and $\tau = \frac{1}{2}\ \tau_s$.

By substituting equations 3. and 4. into equation 2. we see that the power curves for a D.C. motor with respect to both speed and torque are quadratics, as shown in equations 5. and 6.

$$5)\ P_{motor}(\omega) = -(\tau_s/\omega_n)\ \omega^2 + \tau_s\omega$$
$$6)\ P_{motor}(\tau) = -(\omega_n/\tau_s)\ \tau^2 + \omega_n\tau$$

From these equations, we again find that maximum output power occurs at $\tau = \frac{1}{2}\ \tau_s$, and $\omega = \frac{1}{2}\ \omega_n$ respectively.

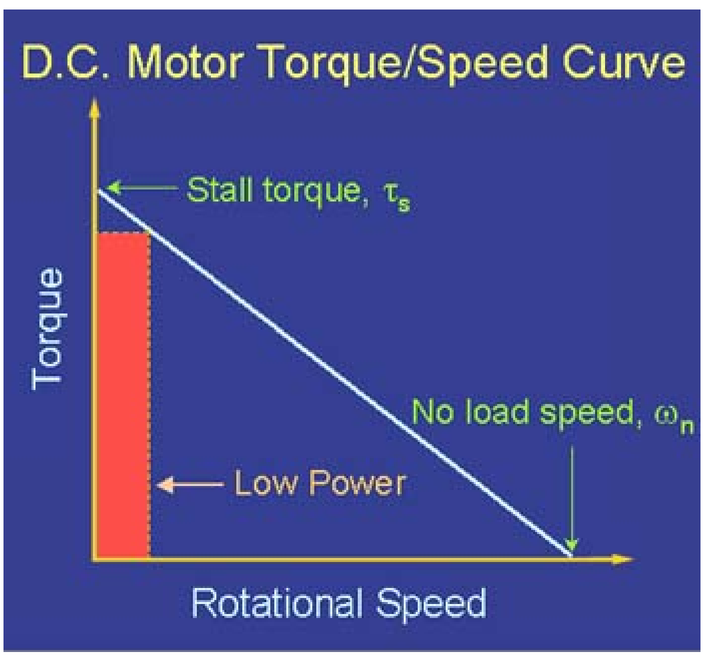



**Figure no. 10**
**Showing lowest power on a motor**

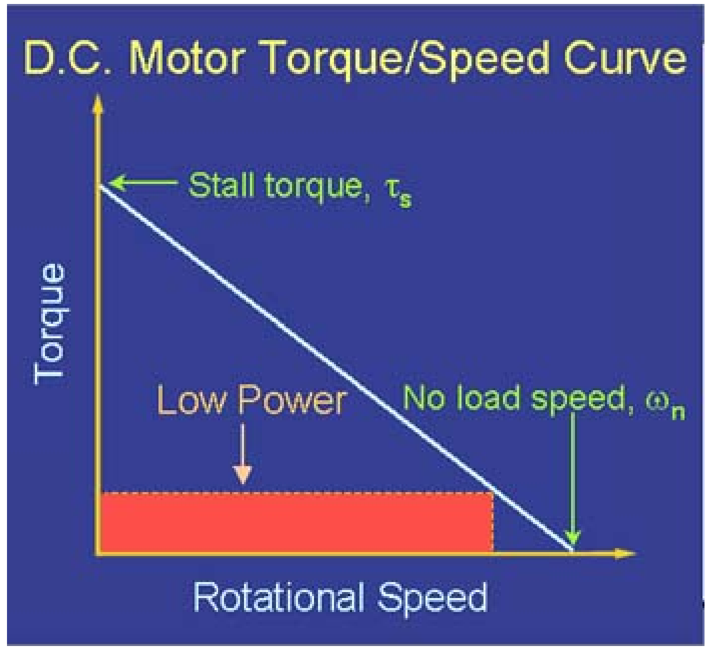



**Figure no. 11**
**Showing lowest power on a motor**

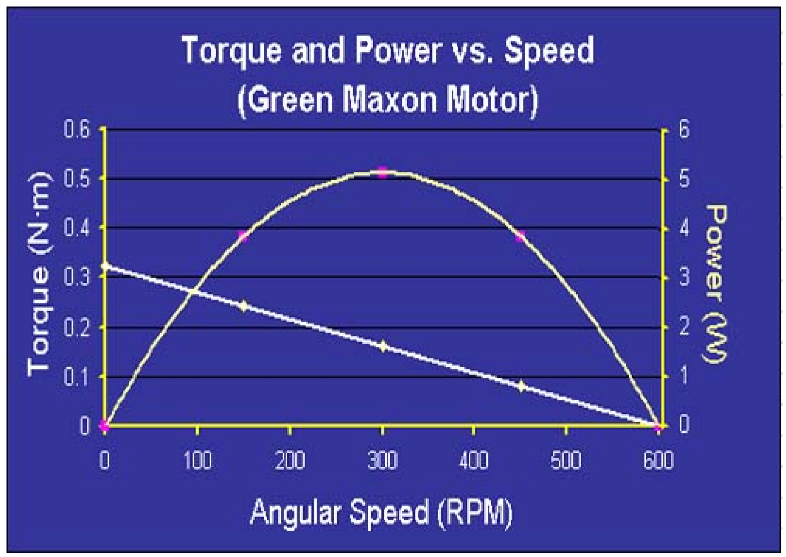



**Figure no.12**
**Relation between torque and power and speed**

**Implementation**

After checking the feasibility conditions, (i.e. economic feasibility, operational feasibility and technical feasibility) adjustable unified wheel opener is designed and it is implemented in real world problems. It worked successfully and finally the output is obtained as such as what is desired. The project has been fabricated which is purely mechanical. All the operations are done manually. To further extend our project as a useful tool, a motor has to be attached to its drive. Such that by providing a motor, it reduces all the human effort in tightening and loosening the wheel's nut. Thus the project can be made an indispensable tool in assembling and dismantling wheels in cars.

## IV. Conclusion

Thus the fabrication of Adjustable Unified Wheel Opener is successfully done. This project will be practically implemented in a four wheeler and it found that the results are positive. The project is economical, and it sustains all the required feasibilities. Adjustable wheel opener is a perfect tool for assembling and dismantling a wheel in a four wheeler.

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